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SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
400 Commonwealth Drive, Warrendale, Pa. 15096

Friction and Wear Characteristics of Silicone-Modified Thermoplastics

Richard F. Smith
Dow Corning Corp.

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THE USE OF PLASTIC as a bearing material has increased greatly in the past decade. Advantages include freedom from maintenance, low cost, light weight, and quiet operation. Many products have used these advantages to achieve a maintenance free classification.

Nylon, acetal and polytetrafluorcarbon (PTFE) have inherent properties which qualify them as self-lubricating. Lubricants have been added to these and other materials for many years, i.e. PTFE, MoS_2 and graphite to decrease wear and friction and increase pressure-velocity limits (L.P.V.). Fillers are also added to improve mechanical strength and dimensional stability.

Highly filled, highly reinforced thermoplastics have been available for several years with LPV values of 20,000. An example is Nylon 66 with 30% glass and 15% PTFE. Although a LPV of 20,000 is suitable for many low load, low speed applications, a LPV of 50,000 is required for plastics to compete with metals.

Lubricants for plastics must be heat stable to withstand processing temperatures which often are as high as 600°F. They must also be compatible to some extent with the base resin to insure little or no migration and subsequent contamination of nearby parts and equipment. Lubricants, of course, should also have very low surface tension.

ABSTRACT

Self-lubricating plastic bearing materials can be produced by adding a small quantity of silicone fluid directly to the thermoplastic melt. The result is a substantial increase in the critical load-speed (limiting pressure-velocity or LPV) limit of the plastic, above which rapid wear takes place. The magnitude of the improvement in lubricity suggests the possibility of replacing metals with plastics, or replacing expensive plastics with silicone-modified, inexpensive plastics. LPV of some plastics has been raised as much as 1000 percent by the silicone additive, where LPV was measured at high speeds. At low speeds, less improvement is noted, but results are still significant.

Data on the effect of the additive on various thermoplastics will be presented, along with a discussion of the correlation between wear rate and LPV.

The additive also improves the handling properties of plastics, producing better flow, easier release from low-draft molds, and other advantages.

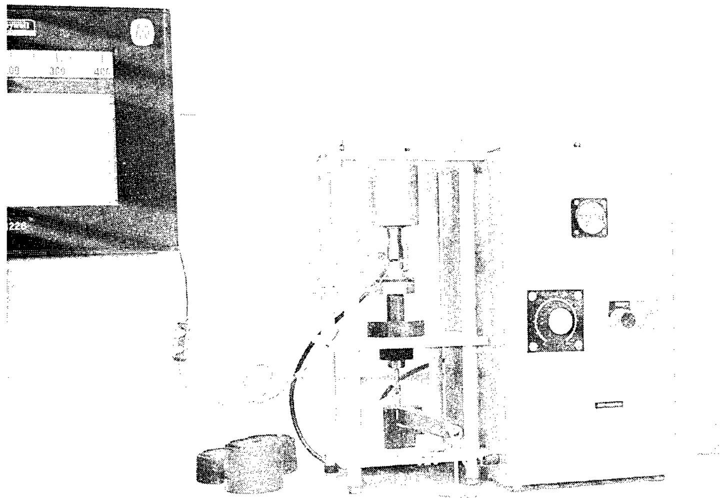

Fig. 1-LFW-6 friction and wear test apparatus

Silicone materials have inherent high temperature stability as well as viscosity stability at temperature. Surface tension is low, 21 dynes/CM (PTFE is 19 dynes/CM) and the degree of compatibility is sufficient to insure no migration of the fluid. Thermoplastic materials can be mechanically blended with high molecular weight silicone fluid to produce a polyblend that exhibits low friction, silicone fluid comprises 3%-10% of the polyblend.

Test Equipment and Procedures-All testing was done on thrust bearings which were run on a LFW-6 friction and wear test apparatus (Fig. 1).

Test specimens were molded on a reciprocating screw injection machine. Care was taken to insure that the bearing surface remained in the "as molded" condition. Grease and dirt contamination were carefully avoided. The metal washers against which the samples were run were standard test pieces with controlled surface finish and hardness (Fig. 2).

Limiting Pressure Velocity-Limiting Pressure Velocity (LPV) is an important design characteristic representing the maximum pressure that a bearing material will function at a given velocity. The product of these (pressure and velocity) results in a convenient numerical system for comparing materials. LPV is determined by establishing a constant velocity and loading the bearing at increments of thirty minutes or when friction and temperature stabilize. Failure may occur due to excessive wear or when bearing temperature or friction fail to stablilize. This failure point is the LPV. Equilibrium torque is recorded throughout the test which enables calculation of coefficient of friction at any given loading.

Wear-Wear rates were determined by measuring sample thickness before and after testing. Wear test for each material was run under a controlled set of conditions. This method eliminates the need for a "K" factor which was found to be very erratic. Wear is often expressed as a constant (K) and most design engineers are familiar with the equation W=K(FVT). This expression, states that wear is

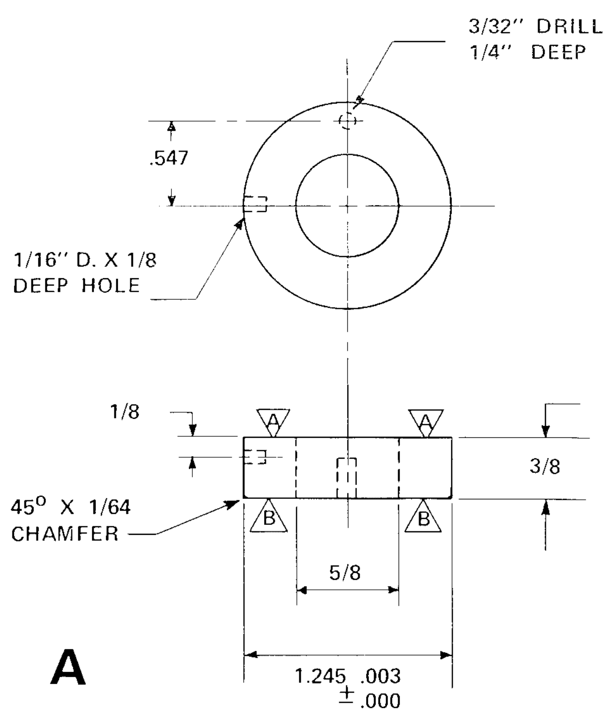

Fig. 2A-Specifications of metal thrust washer

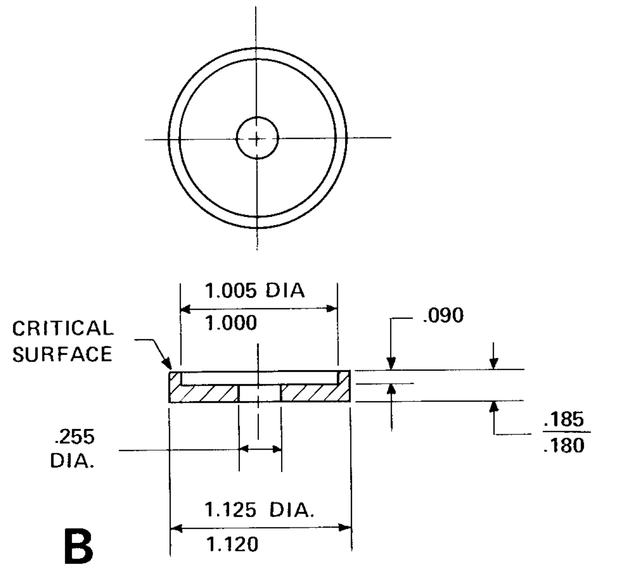

Fig. 2B-Specifications of plastic test pieces

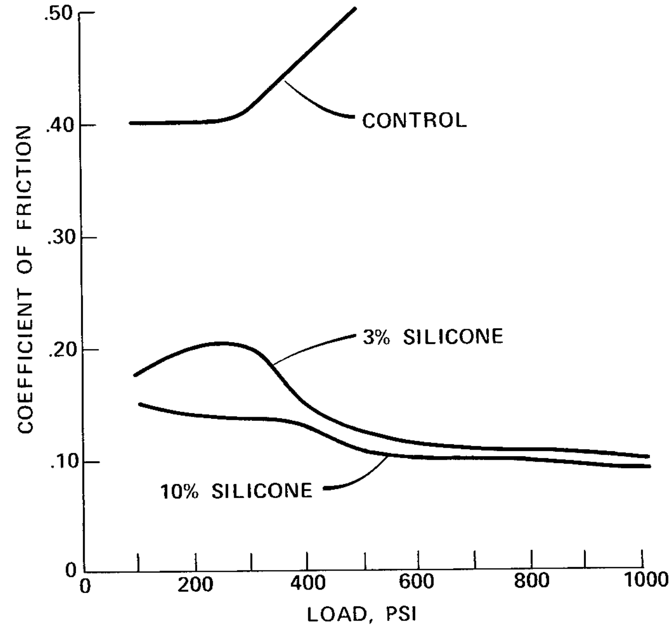

Fig. 3-Nylon 66-coefficient of friction-50 fpm

proportional to a multiple of pressure velocity and time. This formula neglects several variables, i.e. thermal conductivity, surface stresses and hardness. The simple thickness measurement method was found to be much more reproducable under a controlled set of conditions.

Test Results-Three resins were evaluated in this study: Nylon 66, Acetal and Polycarbonate. Three lubricants were compared in Nylon 66: PTFE, MoS_2 and Silicone. Acetal and Polycarbonate were evaluated with and without silicone as a lubricant.

Nylon-The coefficient of friction of Nylon 66 is reduced by more than 50% when 3% silicone fluid is added as a polyblend, higher levels are even more effective (Fig. 3). Comparing silicone fluid to PTFE and MoS_2 resulted in 3% silicone exhibiting lower friction and wear values and the LPV increased by a factor of four vs. a increase factor of two for PTFE and very little improvement with MoS_2. A 10% addition of silicone gave more dramatic results. Table 1.

Glass filled Nylon 66 with silicones as a lubricant had properties very similar to the unfilled resin. The combination of glass and PTFE or MoS_2 showed a LPV improvement factor of two vs. three for silicone. Table 2.

Acetal-Silicone fluid at levels of 2% and 10% added to an acetal homopolymer resulted in improved friction, wear and LPV values. Table 3. The optimum level for this material would appear to be in the 3% to 5% range, more data is required for confirmation.

Polycarbonate-This resin without a lubricant has a very low LPV. The addition of either silicone or PTFE results in an improvement factor of

Table 1-Nylon 66

PROPERTY	CONTROL	3% SILICONE	10% SILICONE	15% PTFE	5% MOS_2
COEFFICIENT OF FRICTION 100 PSI, 100 FPM					
STATIC	.35	.20	.18	.20	.30
DYNAMIC	.38	.12	.14	.22	.35
WEAR RATES - (100 PSI, 50 FPM) (IN./HR. X 10^{-3}	28	.4	.10	1.8	20
PV LIMITS @ 100 FPM	7,200	30,000	60,000	14,500	10,000

Table 2-30% Glass Filled Nylon 66

PROPERTY	METHOD	UNITS	CONTROL	3% SILICONE	15% PTFE	5% MOS_2
COEFFICIENT FRICTION STATIC			.33	.11	.20	.20
DYNAMIC (100 PSI, 100 PFM)	(DOW CORNING) THRUST BEARING	----	.40	.15	.22	.29
WEAR RATE (100 PSI, 50 FPM)	(DOW CORNING) THRUST BEARING	IN X 10^{-3}/HR.	14	0.8	1.2	9
PV LIMIT (100 FPM)	(DOW CORNING) THRUST BEARING	---	10,000	29,800	21,000	20,000

Table 3-Acetal (Homopolymer)

	CONTROL	2% SILICONE	10% SILICONE
COEFFICIENT OF FRICTION 50 FPM-100 PSI - DYNAMIC	.4	.30	.18
WEAR RATES (100 PSI, 50 FPM) IN/HR X 10^{-3}	20.09	5.2	.11
PV LIMITS @ 50 FPM	6000	9600	> 50,000

Table 4-Polycarbonate

PROPERTY	METHOD	UNITS	CONTROL	3% SILICONE	15% PTFE
COEFFICIENT FRICTION STATIC		---	.30	.09	.15
DYNAMIC (100 PSI, 100 FPM)	(DOW CORNING) THRUST BEARING		.39	.11	.19
WEAR RATE (100 PSI, 50 FPM)	(DOW CORNING) THRUST BEARING	IN. X 10^{-3}/HR.	5.5	.16	.23
PV LIMIT (100 FPM)	(DOW CORNING) THRUST BEARING	---	700	23,000	19,000

Table 5-Nylon 66-Physical Properties

PROPERTY	ASTM TEST METHOD	UNITS	CONTROL	3% SILICONE	15% TFE	5% MS
TENSILE STRENGTH	D-638	PSI	11,900	11,500	9,000	11,000
ELONGATION	D-638	%	12.8	23.6	9.3	5.1
FLEX MODULUS	D-790	PSI	397,000	368,000	365,000	350,000
IZOD IMPACT NOTCHED 1/4"	D-256	FT. LB./IN.	.85	.94	.72	.72
HEAT DEFLECTION TEMP. @ 264 PSI	D-648	^{o}F	220	220	225	230
SPECIFIC GRAVITY	D-792	---	1.14	1.15	1.23	1.18

Table 6-30% Glass Filled Nylon 66-Physical Prcp-
erties

PROPERTY	ASTM TEST METHOD	UNITS	CONTROL	3% SILICONE	15% TFE	5% MOS_2
TENSILE STRENGTH	D-638	PSI	21,000	23,000	20,000	23,000
ELONGATION	D-638	%	3.0	3.2	2.2	2.4
FLEX STRENGTH	D-790	PSI	33,200	32,800	27,500	27,000
IZOD IMPACT NOTCHED 1/4"	D-256	FT.LB/IN.	1.7	1.8	1.5	1.5
HEAT DEFLECTION TEMP. @ 264 PSI	D-648	^{o}F	485	485	475	480
SPECIFIC GRAVITY	D-792	---	1.37	1.40	1.48	1.42

Table 7-Acetal (Homopolymer)-Physical Prcperties

PROPERTY	ASTM TEST METHOD	UNITS	CONTROL	3% SILICONE
TENSILE STRENGTH	D-638	PSI	8700	7550
ELONGATION	D-638	%	10.5	33.6
MODULUS X 10^5	D-790	PSI	3.58	3.33
IZOD IMPACT	D-256	FT LBS/IN.	1.08	1.12

Table 8-Polycarbonate-Physical Properties

PROPERTY	ASTM TEST METHOD	UNITS	CONTROL	3% SILICONE	15% TFE
TENSILE STRENGTH	D-638	PSI	8300	8000	6500
ELONGATION	D-638	%	90.0	90.0	11.0
FLEX MODULUS	D-790	PSI	320,000	318,000	297,000
IZOD IMPACT NOTCHED 1/4"	D-256	FT. LB./IN.	2.8	10.0	3.5
HEAT DEFLECTION TEMP. @ 264 PSI	D-648	^{o}F	265	265	271
SPECIFIC GRAVITY	D-792	---	1.20	1.21	1.30

30 which puts this material in a useful range for many applications. Friction and wear values of the silicone lubricated system are somewhat lower than those recorded for PTFE. Table 4.

Physical Properties-Tables 5-8 show physical properties of the three resins tested in this study. Silicone fluid has little effect on the properties of most thermoplastic materials. Slight decreases in tensile strength and an increase in elongation are normally seen. Modulus and impact strength are affected very little with the exception of polycarbonate where an increase in impact strength was noted.

Processing-Silicone fluid can be added to injection molding equipment or extrusion equipment by utilizing a metering pump to produce either a silicone concentrate or a preblended polyblend at any desired level, the pelletized extruded product can then be injection molded without problems. A metering pump can also be used to add fluid directly to injection molding equipment. Each of these methods results in excellent dispersion of the fluid in a

molded part.

Silicone fluids are also useful as processing aids. Low levels, .2% to 1%, in many resins will impart: excellent release, improved flow, reduced part warpage and in many cases, enable shorter cycle times.

Conclusions-Silicone fluid is an effective lubricant for most thermoplastic resins. Levels of 3% to 10% will out perform other lubricants, i.e. PTFE and MoS_2. Physical properties are effected very little when silicone fluid is mechanically blended into a resin to form a polyblend. Fluid can be added to molding equipment in pellet form or by metering directly into injection molding equipment.

REFERENCES

1. Nicholas Walton, "Plastic Bearings", Machine Design, 1972.
2. Bertrand Picour and Richard A. Scherer, "Designing Plastic Bearings", SPE Journal, 1972.
3. Barry Arkles and John Theberge, "Migratory Internal Lubrication of Thermoplastic Resins", ASLE/ASME Joint Conference, Atlanta, 1973.
4. A. W. Duncan and R. F. Smith, Modern Plastics, 1973.
5. F. W. G. Fearon and R. F. Smith, "American Chemical Society International Symposium on Advances in Polymer Friction and Wear", Los Angeles, 1974.

Society of Automotive Engineers, Inc.
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